Text table 5-6.
Percentage of high school graduates earning credits in mathematics courses, by gender and race/ethnicity: 1982 and 1994

Year of graduation and characteristic	Mathematics course			
	General Math	Algebra 2	Geometry	Calculus
1982				
All	30	36	46	5
Male	32	36	45	5
Female	27	35	46	4
White	25	40	51	5
Asian/Pacific Islander	17	56	65	13
Black	47	24	29	1
Hispanic	43	20	26	2
American Indian/Alaskan Native	41	19	34	4
1994				
All	16	58	70	9
Male	18	54	68	10
Female	14	61	72	9
White	15	62	72	10
Asian/Pacific Islander	18	66	76	24
Black	27	44	58	4
Hispanic	16	50	69	6
American Indian/Alaskan Native	19	42	60	4

SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-22 and 5-24.

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courses were diluted—were conducted in only a handful of states and school districts, and in a handful of courses. Moreover, the earlier studies appear to have been conducted not long after the mandates were enforced. Thus, there may have been little opportunity for revisions and improvement.

Curriculum and Instruction

Challenging instruction is at the core of new educational standards. Both the science and mathematics standards present compelling visions of instruction, although neither provides an exact blueprint. Measuring the extent to which this vision is becoming a reality is difficult because available methodologies cannot measure quality directly. Instead, educational researchers have relied most often on indicators of the amount of time students spend studying a subject (classwork and homework) and the content of lessons, as well as the use of instructional resources such as textbooks and technology. Lacking, until quite recently, were indicators that better reflect instruction as a process.

Instructional Time

The question of whether U.S. students spend enough time in school or receiving instruction has persisted for many years and research results on this issue are mixed. Research by Stigler and Stevenson (1991) showed that U.S. students spend fewer hours in school than Japanese students and that U.S. schools allocate less time to core instruction than do other industrialized nations. For example, core academic time in U.S. schools was estimated at 1,460 hours during the four years of high school compared to 3,170 hours in Japan. The National Educational Commission on Time and Learning reported in 1994 that, at the time of the Commission's study, only 10 states specified the number of hours to be spent in academic subjects at various grades. Only 8 others provided recommendations regarding academic time. Based on these and other findings, the Commission concluded that "[T]ime is the missing element in the debate about the need for higher academic standards.... We have been asking the impossible of our students—that they learn as much as their foreign peers while spending only half as much time in core academic studies" (NECTL 1994).

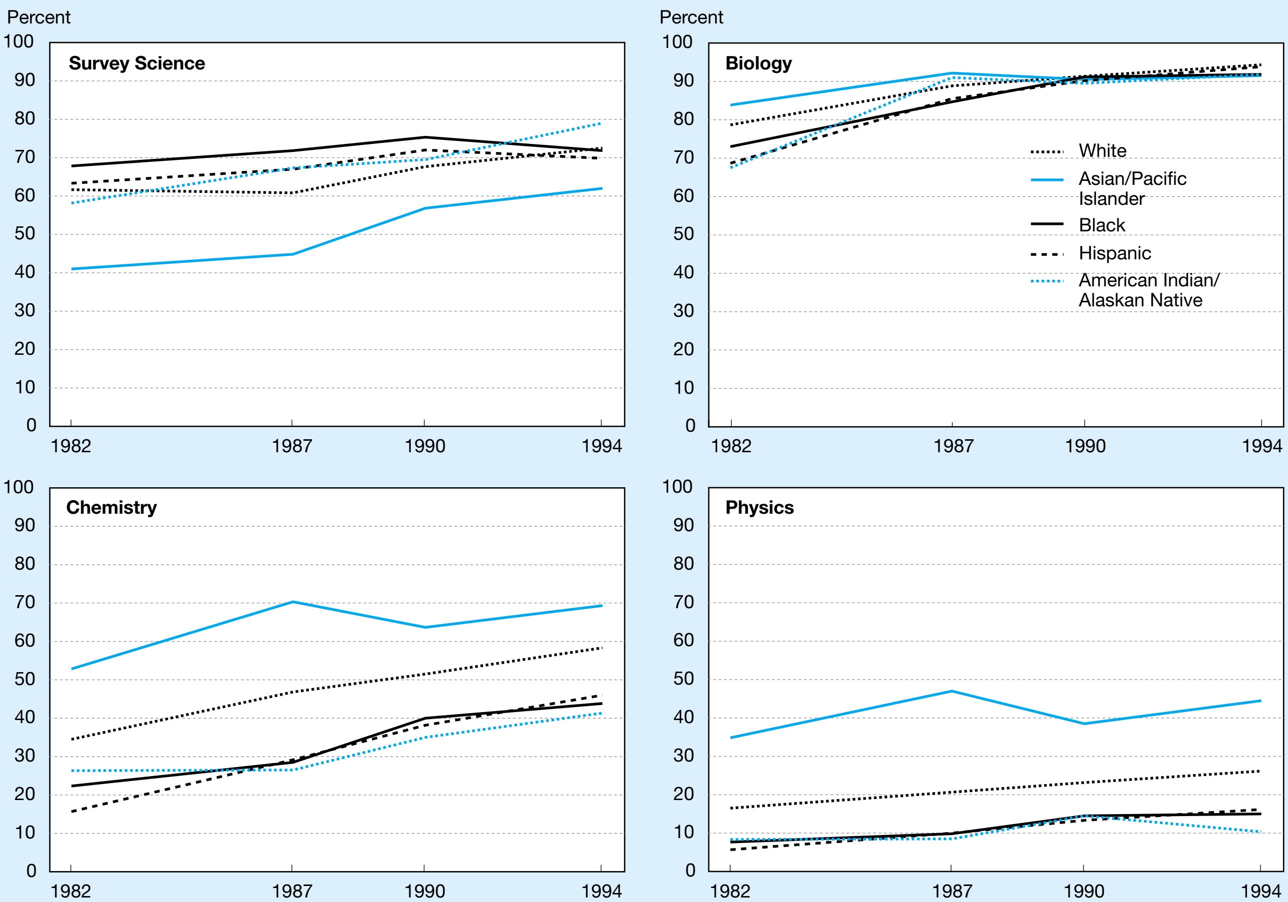
TIMSS data suggested that this may not have been true of mathematics and science in 1995. Students in the United States receive at least as much classroom time in mathematics and science instruction as students in other nations—close to 140 hours per year in mathematics and 140 hours per year in science. Students in Germany, Japan, and the United States spent about the same time on a typical homework assignment, but U.S. students were assigned homework more often, thus increasing total time spent studying in the two subjects (Beaton et al. 1996b; NCES 1996a, 1997b, and 1997c). (See figure 5-16.) Certain caveats are necessary in interpreting results on instructional time. First, in other nations—particularly Japan—students participate in extracurricular mathematics and science activities in after school clubs. Second, disruptions for announcements, special events, and discipline problems in U.S. classrooms considerably reduce the amount of allocated time actually spent on instructional activities (Stigler et al. 1999).

Content: Curriculum and Textbooks

Analyses conducted in conjunction with TIMSS (Schmidt, McKnight, and Raizen 1997) documented that curriculum guides in the United States include more topics than is the international norm. Most other countries focus on a limited number of topics, and each topic is generally completed before a new one is introduced. U.S. curricula, by contrast, follow a "spiral" approach: topics are introduced in an elemental form in the early grades, then elaborated and extended in subsequent grades. One result of this is that U.S. curricula are quite repetitive—the same topic appears and reappears at several different grades. Another result is that topics are not presented in any great depth, giving U.S. curricula the appearance of being unfocused and shallow in appearance.

The Schmidt et al. (1997) study also suggested that U.S. curricula make fewer intellectual demands on students, delaying until later grades topics that are covered much earlier in other countries. U.S. mathematics curricula also were judged to be less advanced, less challenging, and out of step with curricula in other countries. The middle-school curriculum in most TIMSS countries, for example, covers topics in algebra, geometry, physics, and chemistry. Meanwhile, the grade 8 curriculum in U.S. schools is closer to what is taught in grade 7 in other countries and includes a fair amount of arithmetic. Science curricula, by comparison, are closer to international norms in content and in the sequence of topics.

Figure 5-14.
Percentage of high school graduates earning credits in selected science courses, by race/ethnicity: 1982–94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-23.

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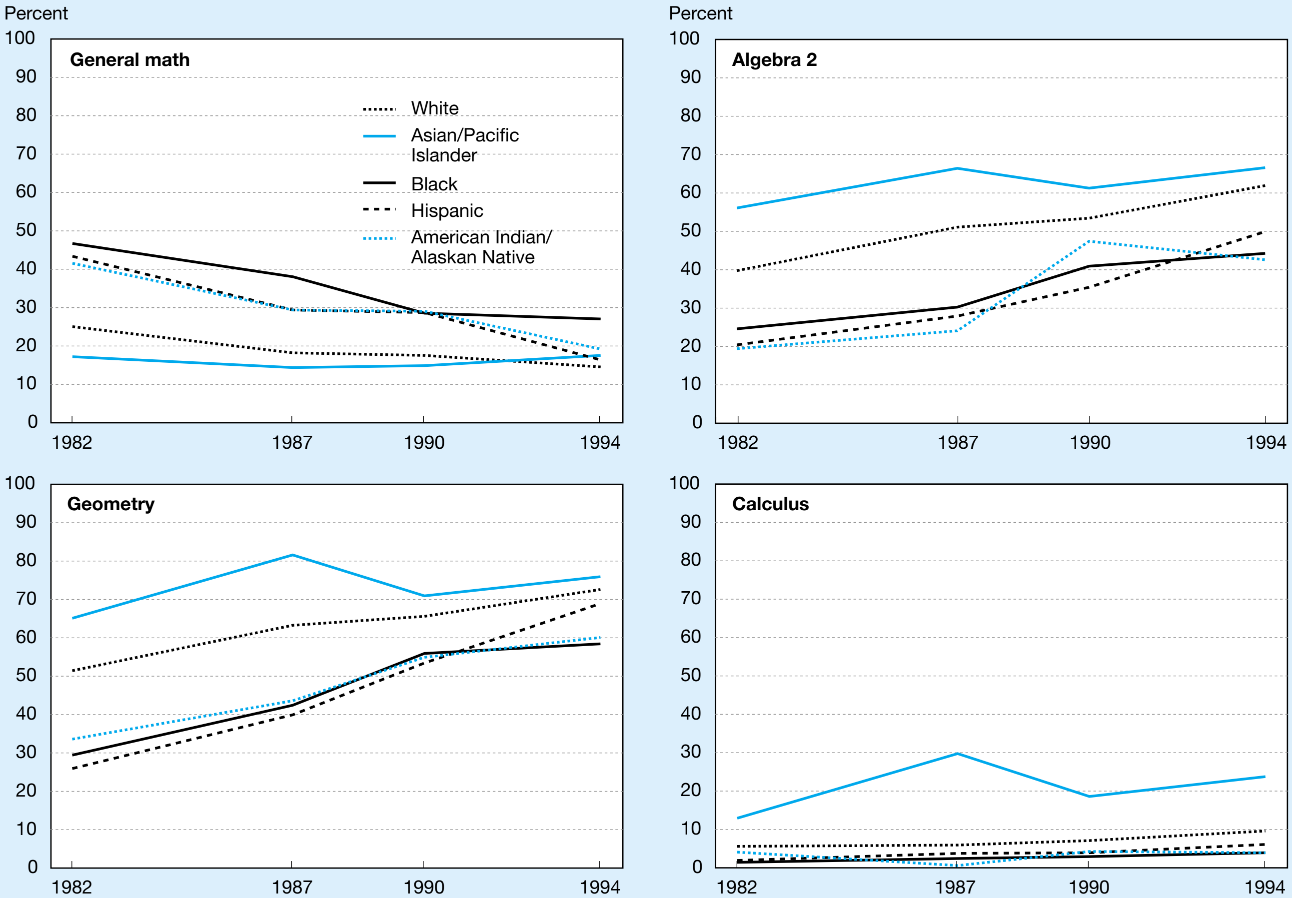
Figure 5-15.
Percentage of high school graduates earning credits in mathematics courses, by race/ethnicity: 1982–94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-24. *Science & Engineering Indicators – 2000*

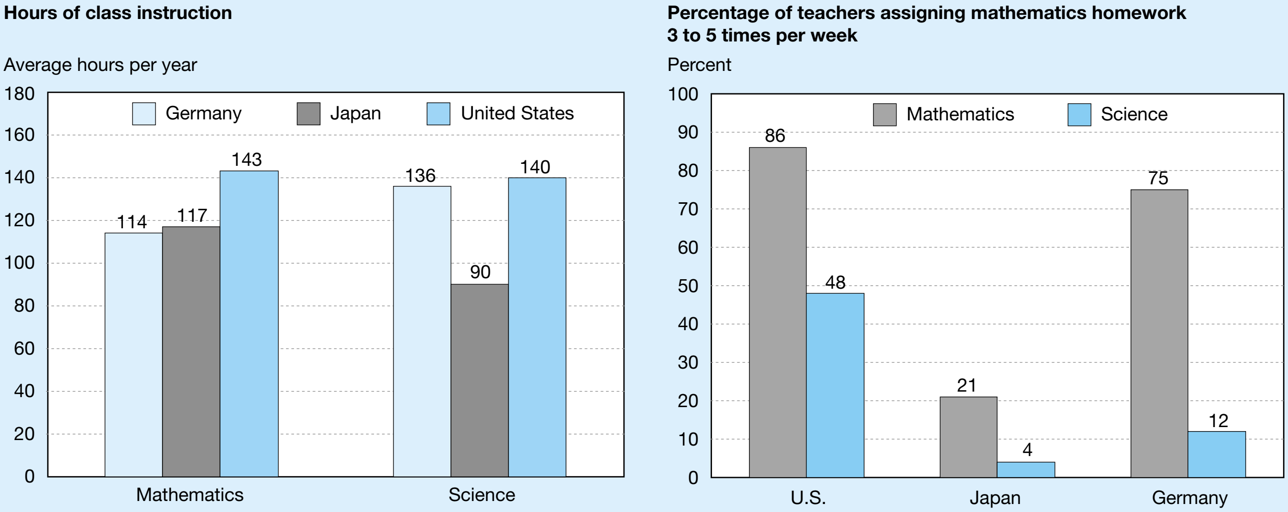
Textbooks reflect the same limitations as documented by curriculum analyses: too many topics with too little coverage and too little development of topics. (See figure 5-17.) Compared to textbooks used in other countries, science and mathematics textbooks in the United States convey less challenging expectations and are repetitive while providing little new information in most grades, a finding reported in earlier research by Flanders (1987) and by Eyelon and Linn (1988). Publishers have made some attempts to reflect the topics and demands conveyed by the educational standards; however, the TIMSS curriculum analyses suggest that when new "standards-referenced" topics are added, much of the old material is retained (Schmidt, McKnight, and Raizen 1997).

Recent studies by AAAS (1999a,b) reinforced the findings of TIMSS and other studies about the limitations of mathematics and science textbooks. AAAS conducted a conceptual analysis of content, based on 24 instructional criteria divided into the following seven categories:

- ♦ Identifying/providing a sense of purpose;
- ♦ Building on/taking into account student ideas;
- ♦ Engaging students in mathematics/engaging students with relevant phenomena;
- ♦ Developing mathematical ideas/developing and using scientific ideas;
- ♦ Promoting student thinking about mathematics/about phenomena, experience, and knowledge;
- ♦ Assessing student progress; and
- ♦ Enhancing the mathematics/science learning environment.

The "AAAS Project" presents the 24 criteria used in evaluating middle school science textbooks. Middle school mathematics textbooks were evaluated using parallel criteria. (See sidebar, "AAAS Project.")

Figure 5-16.
Selected characteristics of grade 8 mathematics and science instruction in Germany, Japan, and the United States: 1994–95



NOTE: Data are from the Third International Mathematics and Science Study.

SOURCE: National Center for Education Statistics (NCES). 1996. *Pursuing Excellence: A Study of U.S. Eighth Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context.* NCES 97-198. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

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The study examined 9 middle-grade science texts and 13 mathematics texts. The samples included the most widely used texts in both subjects. Each text was evaluated by two independent teams of middle-school teachers, curriculum specialists, and science/mathematics education professors. With funding from NSF, AAAS developed and tested the evaluation procedure over a three-year period in collaboration with over 100 scientists, mathematicians, educators, and curriculum developers. On a 0-to-3-point scale (where 3 represents “satisfactory”), all 9 science textbooks scored below 1.5. Six mathematics texts scored below 1.5, while only half that number scored above 2.5 points (AAAS 1999a,b).

Instructional Practice

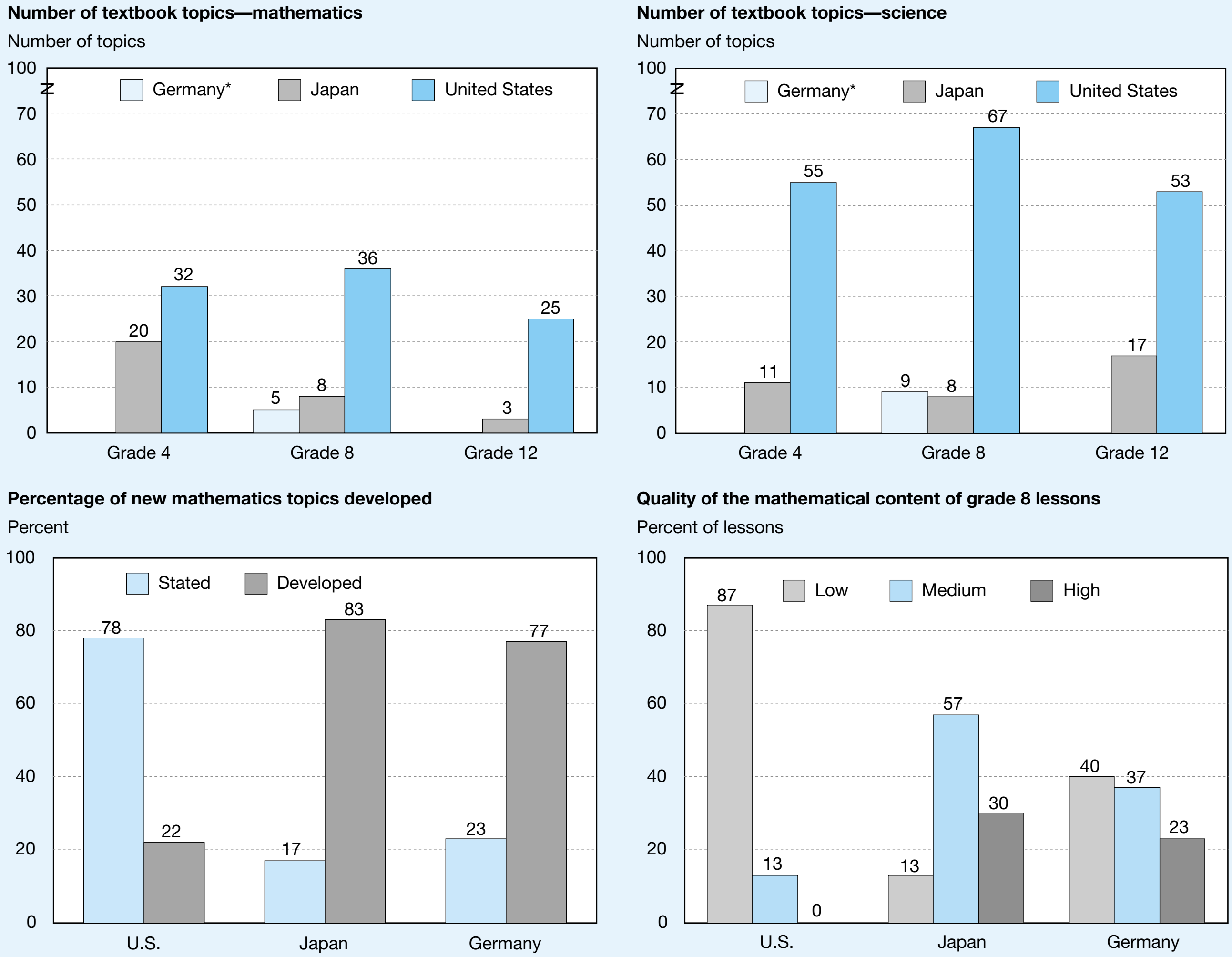
Most information about instructional practice has come from surveys in which teachers were asked about their use of specific aspects of their teaching. In a recent survey, 82 percent of full-time U.S. mathematics teachers and 74 percent of full-time science teachers gave themselves good grades on using practices consistent with educational standards in their fields (NCES 1999a). But classroom observational studies, which have added depth and dimension to depictions of practice, often painted quite a different picture. These studies demonstrated that it is relatively easy for teachers to adopt the surface characteristics of standards-based teaching but much harder to implement the core features in everyday classroom practice (Cohen 1991, Spillane and Zeuli 1999, and Stigler et al. 1999).

The TIMSS video study of grade 8 mathematics instruction is a case in point. Lessons in U.S., German, and Japanese classrooms were fully documented, including descriptions of the teacher’s actions, the students’ actions, the amount of time spent in each activity, the content presented, and the intellectual level of the tasks students were given in the lesson (Stigler et al. 1999). These findings identified four key points:

- The content of U.S. mathematics classes requires less high-level thought than classes in Germany and Japan;
- U.S. mathematics teachers’ typical goal is to teach students how to do something, while Japanese teachers’ goal is to help them understand mathematical concepts;
- Japanese classes share many features called for by U.S. mathematics reforms while U.S. classes are less likely to exhibit these features; and
- Although most U.S. mathematics teachers report familiarity with reform recommendations, relatively few apply the key points in their classrooms.

Ratings of instructional quality of mathematics instruction in eighth grade classrooms provided by mathematicians indicated approximately 30 percent of lessons in Japanese classrooms as “high quality” and 13 percent as “low quality.” In German classrooms, 23 percent of lessons received high ratings and 40 percent low ratings. In comparison, approximately 87 percent of U.S. lessons were considered low qual-

Figure 5-17.
Selected characteristics of grade 4, 8, and 12 mathematics and science instruction in Germany, Japan, and the United States: 1994–95



*Grade 4 and grade 12 data for Germany not available for this comparison.

NOTE: Data are from the Third International Mathematics and Science Study. Eighth grade algebra texts are not included.

SOURCES: Stigler, J.W., P. Gonzales, T. Kanaka, S. Knoll, and A. Serrano. 1999. *The TIMSS Videotape Classroom Study: Methods and Findings from an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States.* NCES 1999-074. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement; Schmidt, W.H., C.C. McKnight, and S.A. Raizen. 1997. *A Splintered Vision: An Investigation of U.S. Science and Mathematics Education.* Boston, MA: Kluwer Academic Publishers.

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ity and none was considered high quality. (See figure 5-17.) However, due to the small scale of the study, these results are suggestive rather than definitive. The studies are now being replicated on a larger scale in both mathematics and science.

Technology

Throughout the United States, school districts have dramatically increased the access of students and teachers to new forms of technology such as hand-held calculators, desktop computers, and the Internet. Hand-held calculators are owned by almost every student in the United States and are fully integrated into the teaching of mathematics in many U.S. schools. Since 1985, many calculator models have featured built-in graphing software for enhancing teaching and learning by allowing mathematics students to visualize mathematical functions.

The National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards (NCTM 1989) urges the use of calculators to reduce the time spent on paper and pencil methods of calculating so that students can have more time to work problems that foster development of conceptual power. The NCTM suggests that by using this approach, stu-

AAAS Project

Evaluating the Quality of Middle Grade Science Textbooks

Category I. Providing a Sense of Purpose
- Conveying unit purpose
- Conveying lesson purpose
- Justifying activity sequence

Category II. Taking Account of Student Ideas
- Attending to prerequisite knowledge and skills
- Alerting teacher to commonly held student ideas
- Assisting teacher in identifying own students' ideas
- Addressing commonly held ideas

Category III. Engaging Students with Relevant Phenomena
- Providing variety of phenomena
- Providing vivid experiences

Category IV. Developing and Using Scientific Ideas
- Introducing terms meaningfully
- Representing ideas effectively
- Demonstrating use of knowledge
- Providing practice

Category V. Promoting Student Thinking about Phenomena, Experiences, and Knowledge
- Encouraging students to examine their ideas
- Guiding student interpretation and reasoning
- Encouraging student to think about what they've learned

Category VI. Assessing Progress
- Aligning assessment to goals
- Testing for understanding
- Using assessment to inform instruction

Category VII. Enhancing the Science Learning Environment
- Providing teacher content support
- Encouraging curiosity and questioning
- Supporting all students

SOURCE: American Association for the Advancement of Science (AAAS). 1999a. Project 2061. "Heavy Books Light on Learning: Not One Middle Grades Science Text Rated Satisfactory." Available from <<http://www.project2061.org/newsinfo/press/rlo92899.htm>>.

dents develop a stronger basis for understanding how to approach complex problems. Meanwhile, educators who do not share this view have expressed concern that young children in classrooms where calculators are heavily used may not develop proficiency with the basic arithmetic operations.

Both the NAEP and the TIMSS surveys included questions for teachers and students on their level of calculator use in schools. The TIMSS surveys show that 99 percent of eighth grade students and 95 percent of fourth grade students in the United States own calculators. The range was from 76 percent in Norway to 95 percent in the United States and the Czech Republic. (See text table 5-7.) In the United States, many schools provide calculators for use by students who do not own them. School-owned calculators used in fourth grade U.S. classrooms increased from 59 percent to 84 percent between 1992 and 1996 (Hawkins, Stancavage, and Dossey 1998).

Classroom use of calculators is less common among U.S. elementary school students than it is among middle school students in most countries. Although U.S. teachers are more likely than teachers in most other countries to use calculators in the lower grades, about 30 percent still report that they never use calculators. (See text table 5-7.) On the other hand, about the same percentage of these teachers report using calculators to solve complex problems in fourth grade classrooms, about the same proportion of teachers as in Canada and England.

By grade 8, classrooms in nearly all countries use calculators for mathematics instruction. The extent of calculator use is comparable in most countries, except in South Korea and Ireland, where calculators are seldom used in middle school classrooms. A large percentage of U.S. teachers (about three-fourths) report that they use calculators to help students solve complex problems.

Computers also are becoming ubiquitous in U.S. schools. In the 1997/98 school year, 71 percent of teachers in grades 4 to 12 had students use computers during class time at some point during the school year. (See appendix table 5-26.) Teachers of secondary academic subjects are less likely to have their students use computers than are elementary teachers of self-contained classes or teachers of business and vocational subjects. Overall, about one-half of mathematics teachers (49 percent) reported some use of computers by students during at least one of the classes they taught that year, compared to 75 percent of English teachers. Although computers were introduced to classrooms almost two decades ago, computers are a form of technology that still may be unfamiliar to many teachers. The results of a 1998 survey reported that only one teacher in five felt "very well prepared" to integrate education technology in the subject they taught (NCES 1999b).

In addition to issues of professional development related to computer use, equity issues also have been a concern. A study by the Educational Testing Service (ETS) examined the relationship of achievement on the 1996 NAEP mathematics assessment to computer access, frequency of use, and level of teachers' professional development in technology (ETS 1999). Students who scored the highest among eighth graders were more likely to use computers at home, more likely to have teachers with recent professional development in technology, and more likely to have teachers who used computers to teach higher order thinking skills. In general, the study concluded that the use of computers can be positively associated with student achievement when it is used in productive ways such as increasing use of higher order concepts and when teachers are informed of their use (ETS 1999).

Studies have also found that socioeconomic variables influence computer access (Becker 1997 and ETS 1999). There were few differences in computer use at school among fourth or eighth graders, except that black children in the fourth grade used the computer somewhat more often. Black, poor,

Text table 5-7.
Mean students mathematics scores and percent of students and teachers reporting hand-held calculator use in 4th and 8th grade, by country: 1995

	Mathematics scores		Fourth grade				Eighth grade teachers		
			Student		Teacher				
Country	4th grade	8th grade	Percent having calculators in home	Never use calculator in math class	Never use in class	Use to solve complex problems	Never use	Use every day	Use to solve complex problems
Singapore	625	643	93	96	97	1	1	82	82
Korea	611	607	87	93	86	3	76	1	4
Netherlands	577	541	93	90	85	2	0	81	67
Czech Republic	567	564	95	63	54	8	3	74	80
Austria	559	539	91	96	98	0	2	87	70
Ireland	550	527	86	91	88	3	68	11	7
United States	545	500	95	34	29	26	8	62	76
Hungary	548	537	88	90	78	5	29	60	53
Canada	532	527	87	51	37	23	5	80	86
England	513	506	93	15	8	28	0	83	73
Norway	502	503	76	89	93	1	2	82	72
New Zealand	499	508	90	18	5	50	7	66	70

SOURCES: Mullis I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1997. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center; Beaton, A., M. Martin, I. Mullis, E. Gonzalez, T. Smith, and D. Kelly. 1996a. *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center.

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urban, and rural students in eighth grade were less likely to have access to a computer at home, less likely to have teachers who use computers for learning higher order skills, and less likely to have mathematics teachers who had participated in professional development related to technology in the five prior years (ETS 1999).

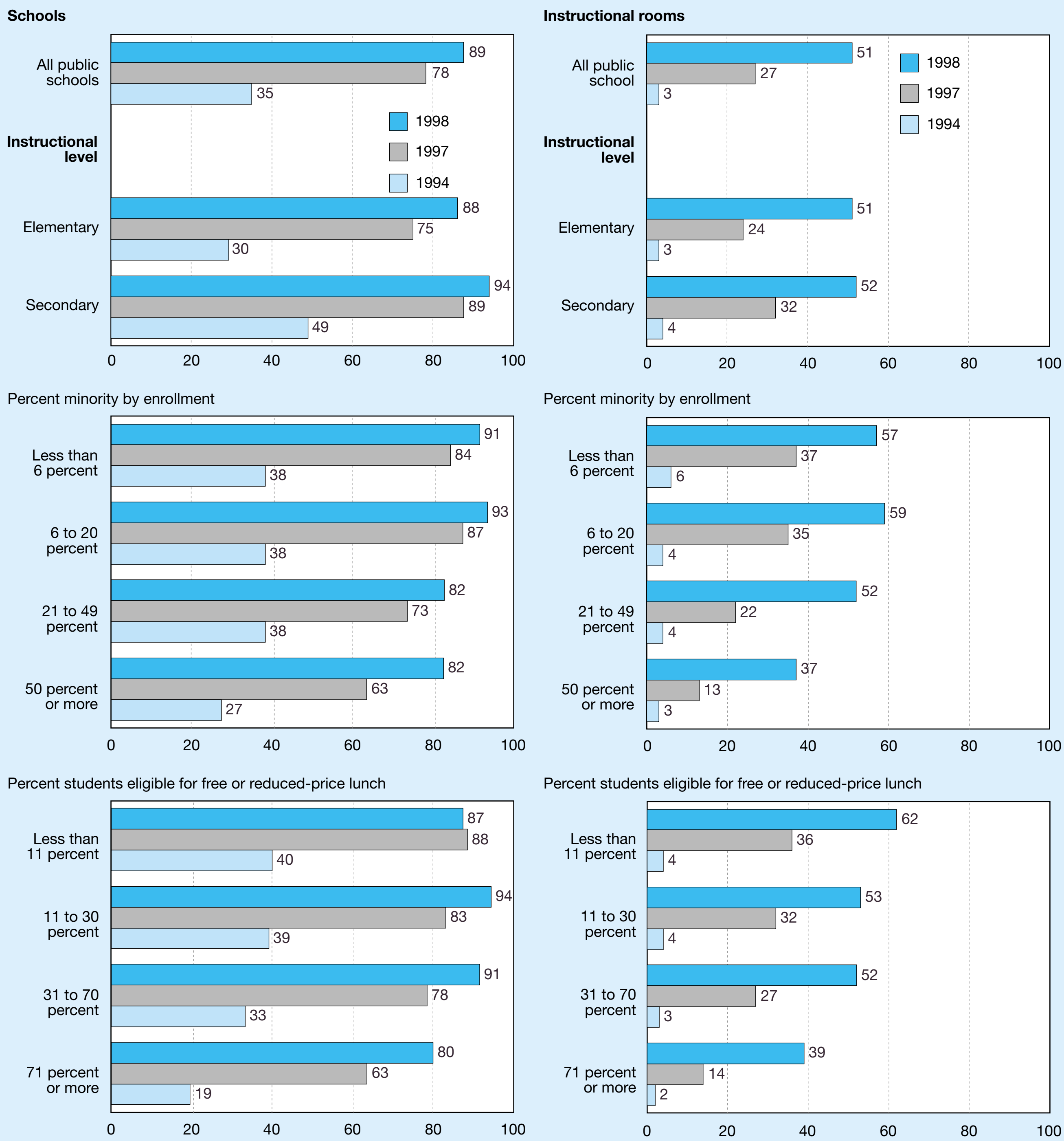
Until recently, "technology in schools" meant computers. Presently the newest technology being explored in schools is the Internet. By 1998, about 90 percent of all schools reported they had access to the Internet, an increase of about 15 percentage points each year since 1994, when 35 percent of schools reported Internet connectivity. (See figure 5-17.) However, for some of these schools only one computer was linked to a single phone line. It is remarkable, therefore, that about half of classrooms had access to the Internet in 1998 (NCES 1998d, Becker 1999a,b). (See also chapter 9, "Significance of Information Technologies.")

Another recent study showed that teachers with several computers in the classroom are much more likely to perceive the value of the Internet and to use the Internet for student research projects (Becker 1999a). However, results also showed that mathematics teachers are the least likely of all teachers to perceive Internet use as having value for classroom instruction. Only about 12 percent of mathematics teachers used the Internet themselves compared with 20 percent of other teachers (Becker 1999a,b). Even as access to computers and other forms of technology in the classroom has increased rapidly, newspaper reports suggest that many teachers (75 percent of those responding to an *Education Week* survey) believe that there were still not enough Internet-connected computers in the classroom to make good use of them for instruction (*Education Week* 1999).

Figure 5-18 suggests that although there has been rapid growth in Internet access and use in all types of schools, there also are equity issues to be resolved. In Fall 1998, about 90 percent of schools at the lowest poverty levels had Internet access, compared to 80 percent at the highest poverty levels (based on the percentage of students receiving reduced-price lunches). Although the percentage of classrooms with Internet connections also increased greatly in one year for all categories of schools, inequities were apparent at this level as well. In Fall 1998, 40 percent of classrooms in high poverty schools had Internet access, compared to 62 percent of classrooms in low poverty schools. Unequal access to the Internet in schools has led many educators and policymakers to be concerned about developing a "digital divide" that separates poor and minority children from more affluent and white children.

In summary, at the beginning of a new century, classrooms are clearly undergoing a transformation. The rapid changes make descriptions of a "typical" classroom based on survey results a few years old already out of date. More detailed discussion of the growth of information technologies in schools and a review of their effectiveness in education are included in the chapter on information technology.

Figure 5-18.
Percentage of public schools and percentage of instructional rooms having access to the Internet, by school characteristics: 1994, 1997, and 1998



SOURCES: National Center for Education Statistics (NCES). 1995. *Advanced Telecommunications in U.S. Public Schools, K-12.* NCES 95-731; 1996. *Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, 1995.* NCES 96-854; 1997. *Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, Fall 1996.* NCES 97-944; 1998. *Internet Access in Public Schools.* NCES 98-031. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement; and data from the Fast Response Survey System, "Survey on Internet Access in U.S. Public Schools, Fall 1998," FRSS 69, 1998.

See appendix table 5-25.

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Teachers and Teaching

Currently, there are approximately 2.7 million teachers in U.S. public schools: 1.6 million in primary schools and 1.1 million in secondary schools. (See text table 5-8.) By the year 2009, the number of public elementary and secondary teachers is projected to increase by 2.4 percent. (See text table 5-9.) One question facing the education community is whether supply will be sufficient to meet demands in the next ten years. The U.S. Department of Education projects that 2 million teachers will need to be hired in the next 10 years (NCES 1999f). Some analysts maintain that teacher preparation programs will not graduate enough teacher candidates to meet this demand. Others disagree and point out that the critical question is not whether there will be enough teachers to satisfy demand, but enough to assure that every child and every classroom has a competent teacher (Darling-Hammond 1996).

Another aspect of the supply and demand problem for the teaching profession is related to societal changes that have taken place in recent years. As noted earlier, the school population has increased in diversity. From this perspective, the composition of the current teaching force has not kept pace. In 1976, nearly 88 percent of public school teachers were white; in 1996, the estimate was 91 percent (NCES 1997a). Consistent with these numbers, a 1996 survey of state departments of education reported that few students have the opportunity to study science and mathematics with minority teachers: only 14 percent of students taking mathematics and biology, 10 percent taking chemistry, and 7 percent taking physics (Blank and Langeson 1997).

The gender balance in the teaching force has been a matter of interest for some time as well because of the lower representation of women in some areas of science noted earlier in this chapter (NSF 1997a,b). There has been some change in the last two decades, but not always in the desired direction. From 1976 to 1996, the percentage of male teachers increased from 33 percent to 42 percent. In 1985, two-thirds of mathematics and science teachers were male. More recent surveys suggest that the balance is shifting toward equality in the numbers, except in physics, where currently 72 percent of teachers are male (NCES 1998b).

Text table 5-8.
Classroom teachers in public elementary and secondary schools: 1985–2009
(Thousands)

Year	K–12	Elementary	Secondary
1985	2,206	1,237	969
1990	2,398	1,429	969
1995	2,598	1,525	1,073
1999[a]	2,700	1,580	1,120
2000[a]	2,712	1,583	1,129
2005[a]	2,765	1,581	1,184
2008[a]	2,768	1,578	1,190
2009[a]	2,766	1,578	1,188

[a]Projected.

SOURCE: National Center for Education Statistics (NCES). 1999. *Projections of Education Statistics to 2009.* NCES 1999-038. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

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Teacher Qualifications

As new standards for mathematics and science education create higher expectations for student achievement, more is expected of teachers as well. These higher expectations raise the question of what high quality teaching entails. In the absence of completely satisfactory measures of quality, indicators of teacher preparation and qualifications have been used as proxies. Studies show that teacher qualifications make a real difference to achievement.

Results from the 1996 NAEP survey of teachers showed that students with higher mathematics scores were more likely to have teachers who were certified, had more than five years of teaching experience, and, in the case of eighth grade students, had majored in mathematics rather than in any field of education (Hawkins, Stancavage, and Dossey 1998). In science, the results were similar. Students with better achievement had teachers who had college majors in science, were certified in science (eighth grade only), and had more years of teaching experience (O'Sullivan, Weiss, and Askew 1998). Earlier studies also reported a positive relationship between achievement and teacher qualifications (Chaney 1995).

Other studies have confirmed the strength of the relationship between achievement and teacher characteristics. One of those studies demonstrated that, with socioeconomic status controlled, performance differences between white and black students could be explained largely by differences in their teachers' qualifications (Ferguson 1991). Analyses of other data further suggest that better achievement results are obtained when resources are spent to improve the quality of teaching than when the same resources are applied to options such as reducing class size or raising teachers' salaries (Ferguson 1991; Greenwald, Hedges, and Laine 1996).

Degrees Earned

TIMSS survey data indicated that mathematics and science teachers in U.S. schools completed more years of college than their counterparts in most other countries (NCES 1996a, 1997b). A 1998 survey of full-time teachers showed that, in fact, almost all had undergraduate degrees and many had master's or other advanced degrees as well. Overall, approximately 55 percent of high school teachers, 46 percent of middle school teachers, and 40 percent of elementary school teachers held master's degrees (NCES 1998b). Among secondary mathematics and science teachers, approximately 45 percent had advanced degrees, as was true for teachers of other core subjects including English and social studies (NCES 1998b).

Text table 5-9.
Percentage of public secondary school (grades 7–12) teachers in each field without a major or a minor in that field and students taught by those teachers

	English	Math	Science	Life sciences	Physical sciences	Social studies	History
Teachers							
Total	24.1	31.4	19.9	32.9	56.9	19.3	53.1
School poverty level							
Low poverty	20.1	26.8	17.5	29.2	51.3	15.8	46.4
High poverty	25.7	42.8	27.8	40.1	65.1	25.1	60.0
School size							
Small	30.4	41.2	25.5	38.1	64.5	25.5	62.8
Large	22.4	27.5	17.6	30.1	53.7	17.2	48.1
Students taught by teachers							
Total	20.8	26.6	16.5	38.5	56.2	13.4	53.9
Track of class							
Low track	24.7	33.5	20.4	42.3	66.8	14.3	55.1
Medium track	11.8	15.7	9.2	31.4	42.8	8.9	44.9
High track	11.2	20.4	7.2	20.7	43.0	11.2	51.1
Grade level of class							
7th grade	32.2	48.8	31.8	60.4	73.8	23.9	56.3
8th grade	32.9	37.1	23.8	32.9	75.7	19.7	60.5
9th grade	15.7	18.1	10.7	27.9	61.7	8.7	48.7
10th grade	11.1	16.8	8.9	29.3	45.7	8.8	51.1
11th grade	11.2	15.9	6.4	23.5	36.8	6.8	47.0
12th grade	13.9	24.2	13.1	25.3	41.0	11.3	62.4

SOURCE: Ingersoll, R. 1999. "The Problem of Underqualified Teachers in American Secondary Schools." *Educational Researcher* 28, No. 2 (March): 26–37.

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Undergraduate Major

The importance of teachers' academic preparation in undergraduate years has increased as educational standards are more widely adopted. To help students meet high standards, teachers must have a thorough knowledge of their subject matter and a solid understanding of concepts in their fields. Until recently, most states did not require teachers to have academic majors in the fields in which they most often taught.

A 1996 NAEP survey found that the majority of mathematics and science teachers do not have academic degrees in their fields. The data showed that 83 percent of fourth grade students and 32 percent of eighth grade students had mathematics teachers who had college majors in education. Nine percent of fourth graders and 49 percent of eighth graders have teachers who majored in mathematics. Four and 13 percent of these students, respectively, had teachers with a major in mathematics education. NAEP survey data showed that 74 percent of fourth grade students and 20 percent of eighth grade students had science teachers who majored in education (excluding science education). Five percent of fourth grade students and 45 percent of eighth grade students had science teachers who majored in science. Five and 11 percent of these students, respectively, had teachers who majored in science education.

Examining data from another perspective, 1996 NAEP survey findings indicated that only 9 percent of fourth grade students had teachers who majored in mathematics and an additional 4 percent had teachers who majored in mathematics education. Approximately 49 percent of eighth grade students were taught by teachers with degrees in science and 13 percent by teachers with degrees in science education (NCES 1998c).

Experience

Teaching experience is another widely used quality indicator. The 1998 NCES teacher survey showed that the majority of full-time teachers had 10 or more years of experience in their profession (NCES 1999b). Results of the 1996 NAEP survey showed that one-half of the students taking mathematics and science in grades four and eight had teachers who had been in the profession 11 years or longer. An important concern raised by the National Commission on Teaching and America's Future is that teachers with the least experience often are placed in central city schools, where the need for experienced teachers may be greatest (NCTAF 1996).

Certification

Certification is also a factor in determining a teacher's qualifications to teach in a particular field. The 1996 NAEP surveys reported that approximately 32 percent of fourth grade and 81 percent of eighth grade students study mathematics with a teacher certified in mathematics. Close to 25 percent of fourth grade students and 75 percent of eighth grade students study science with teachers certified in some area of science or in science education. Certification and licensing have been contentious issues in the profession for some time now. The National Commission on Teaching and America's Future estimated that, in recent years, approximately 50,000 people have entered classrooms with emergency or substandard licenses (NCTAF 1996).

In- and Out-of-Field Teaching Assignments

Often, secondary school teachers are assigned to courses for which they lack certification or other appropriate preparation. "Out-of-field" teaching is the term applied to this practice. Estimates of the extent of out-of-field teaching vary depending on the criteria used. For example, when the criterion for teaching is a graduate degree in the subject taught, the incidence of out-of-field teaching in mathematics and science is quite high. When the criterion is certification alone, estimates drop to less than 15 percent for both subjects (NCES 1997a). Ingersoll, who has done the most extensive examinations of this phenomenon, defines out-of-field teaching in terms of undergraduate major and minor (Ingersoll 1996, 1999).

Using Ingersoll's definition, out-of-field teaching is most common in physical science (57 percent) and history (53 percent), followed by life sciences and mathematics (33 percent and 31 percent, respectively). (See text table 5-9.) Out-of-field teaching is more common in small schools and in schools with larger numbers of low income or minority students. (See figure 5-19.) Students in lower secondary grades (7 through 9) and students in lower academic tracks experience more out-of-field teaching than students in higher grades and higher ability tracks. Out-of-field teaching is also more widespread in some states than in others (Ingersoll 1996).

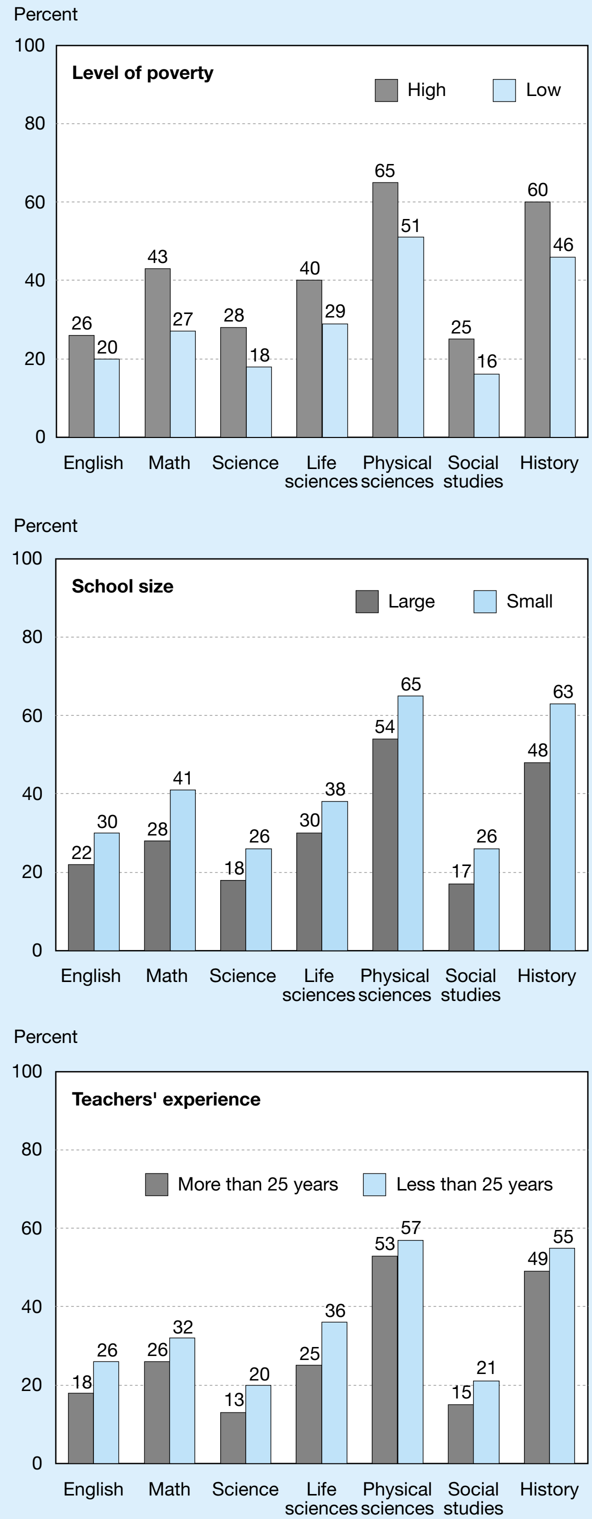
Out-of-field teaching is a major concern to the profession because it is a factor contributing to the number of teachers who are not appropriately prepared for the subjects they teach. Equity issues also fuel these concerns because poor and minority children are more often faced with teachers who are working outside their areas of preparation and expertise (Ingersoll 1996, NCTAF 1996, and Ingersoll 1997).

These findings are consistent with those of a recent study on teachers' perceived preparedness to function in various areas. While 71 percent of teachers feel well prepared to maintain order and discipline in their classrooms, over 36 percent feel well prepared to implement state or district curriculum and performance standards and only 20 percent were prepared to address the needs of limited English proficiency students or students from diverse cultural backgrounds (NCES 1999b).

The Teaching Profession in the 21st Century

Teachers, teacher educators, and state departments of education have been working for at least two decades to upgrade the quality of teaching. Some states and teacher preparation

Figure 5-19.
Percentage of secondary school (grades 7–12) teachers in each field without a major or a minor in that field



SOURCE: Ingersoll, R. 1999. "The Problem of Underqualified Teachers in American Secondary Schools." *Educational Researcher* 28, No. 2 (March): 26–37.

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programs now require teacher candidates to major in an academic subject. Teacher preparation programs are working with school districts to provide candidates with an additional one or two years of study, focused primarily on classroom experience. Induction programs are being developed to provide new teachers with mentors and support during their early years, when the recruits are most likely to leave the profession.

A new teacher education infrastructure is being developed. Standards for accrediting teacher preparation programs have been developed by the National Commission on Accreditation in Teacher Education (NCATE). Standards for licensing beginning teachers and guiding professional development have been formulated by the Interstate New Teachers Assessment and Support Consortium (INTASC), a collaboration of state-level staff and professional organizations concerned with teacher preparation and licensing. Standards for certifying accomplished teaching are being developed by the National Board for Professional Teaching Standards. As envisioned, these standards, aligned closely with each other and with standards for student learning, will form an integrated system that carries the prospective teacher from entry into a teaching program, through licensing and certification, through becoming an accomplished teacher, and on to lifelong professional development (Wise 1989, INTASC 1991, NBPTS 1991, INTASC 1994, Wise and Leibrand 1996, and Darling-Hammond and Ball 1997).

In addition to resolving questions about teacher qualifications, the profession also must resolve equity issues related to the quality of instruction for students in different circumstances. Poorer schools and schools with more minority students are less likely to have qualified teachers when judged by major, certification status, or years of teaching experience. Minority students are less likely to have teachers who are judged as very effective when evaluated using value-added criteria that reflect student growth in achievement (Education Trust 1998). This fact has important policy consequences. Students with the greatest need often are placed in the care of teachers who are least prepared to provide the kind of support they require (Holmes Group 1986; Oakes, Gamoran, and Page 1992; Chaney 1995; Ingersoll 1995, 1996, 1997, 1999).

Conclusion

This chapter presented indicators of changes in U.S. elementary and secondary schools in student achievement, curriculum, instructional practices, and the teaching profession. Observations made about U.S. mathematics and science education in 1947 noted that textbooks were thick and included unnecessary information and that teachers did not have sufficient training in mathematics. Significant efforts have been made to reform elementary and secondary schools since 1947 such as those stimulated by Sputnik in 1957, the National Commission on Excellence in Education 1983, and the National Education Goals that grew out of the Governor's summit of 1990. The national policy goals and educational standards for mathematics and science education set new and higher expectations for U.S. schools, students, and teachers. In the 1990s, NSF carried out a program of systemic reform to seek improved methods of education. The indicators in this chapter were chosen to measure how close the Nation has come to meeting those expectations.

A higher proportion of students graduate from high school having taken advanced courses in mathematics and science than did their counterparts three decades ago. As measured by the National Assessment of Educational Progress, student achievement in mathematics and science has increased since the mid-1970s, but little change has occurred since 1990. The achievement of students in most demographic groups has improved significantly since the late 1970s. Much of that improvement, however, has been in lower skill areas. There have been small increments in the proportion of students achieving at higher levels of performance, but not nearly enough to conclude that National Education Goal 3 has been well met. Many students leave elementary and middle school without strong foundations in mathematics and science. This is a particular concern when regarding black and Hispanic students who continue to perform far below their white counterparts.

The performance of females compared with males on tests of mathematics and science has changed somewhat during the past two decades. At elementary school, few significant differences in performance levels for either mathematics or science were observed in 1996, the last year NAEP was available. At middle school, no differences are detectable for mathematics, but some difference between genders exists in science. At high school, the tendency of males to outperform females is still detectable in mathematics and clearly evident in science, although the differences have been narrowing since 1977.

Among the National Education Goals is the assertion that the mathematics and science achievement of U.S. students will be first in the world by the year 2000. Fourth grade students come close to meeting this expectation in both subjects, but grade 8 and grade 12 U.S. students perform below their peers in other countries according to results collected in 1995 for the Third International Mathematics and Science Study (TIMSS).

An explicit goal of educational standards for mathematics and science is that all students—without regard to gender, race, or income—participate fully in challenging coursework and achieve at high levels. The disparate performance among racial/ethnic groups is still observed in NAEP assessments. Asian/Pacific Islander and white students are better represented in advanced courses than are black and Hispanic students. Asian/Pacific Islander and white students continue to outperform black and Hispanic students. Students of color and less-affluent students still have less access to high-end technology and less access to teachers with the proper education and certification in the subjects they teach. Although differences among ethnic groups continue, there have been important improvements: black and Hispanic students are